Interaction between natural benthic communities and cultivated blue mussels in Belfast Lough:
Role in top-down control of eutrophication

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What is shellfish aquaculture?









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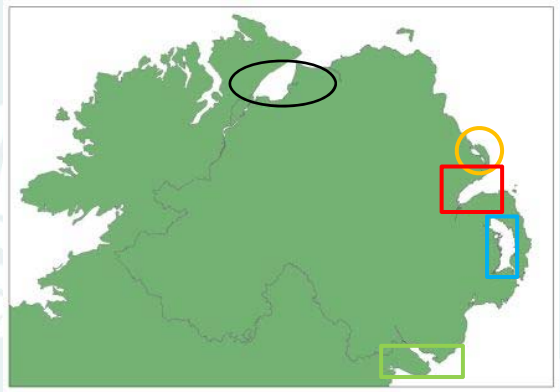
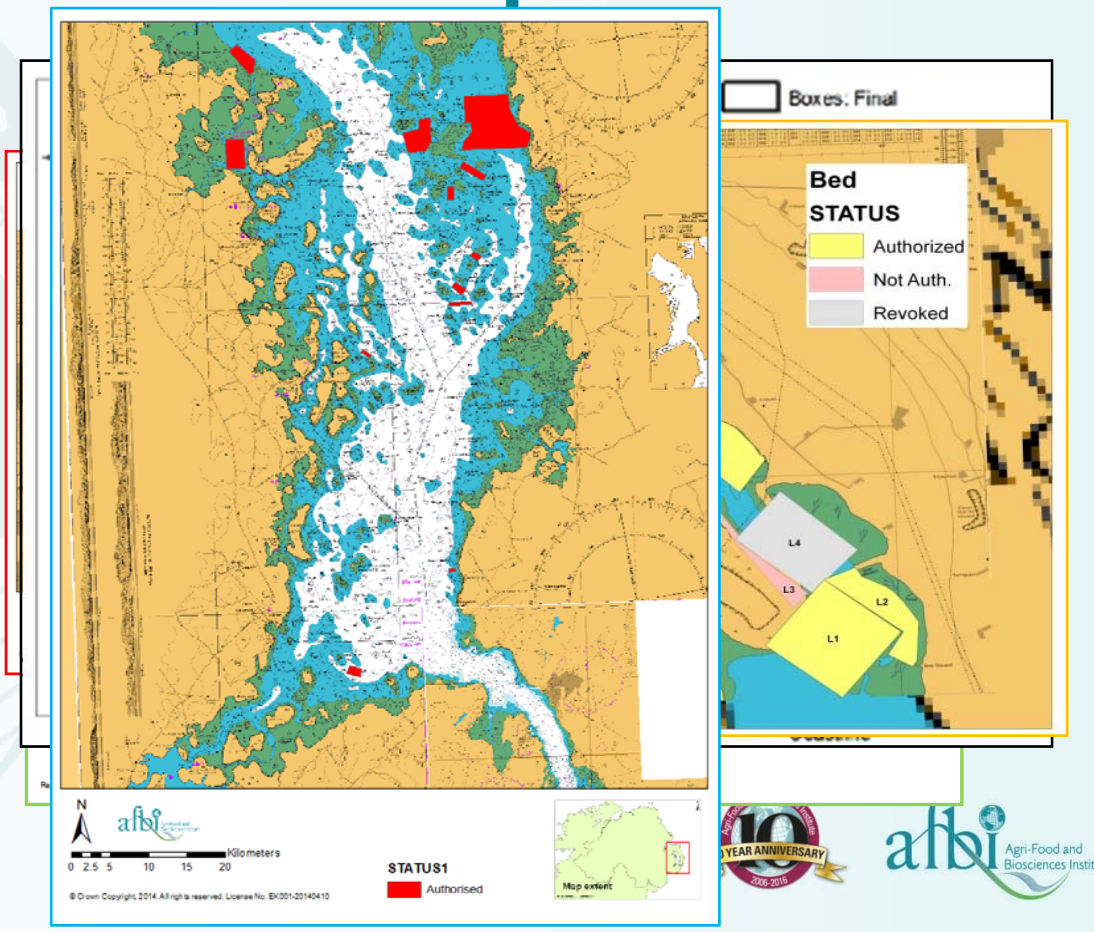
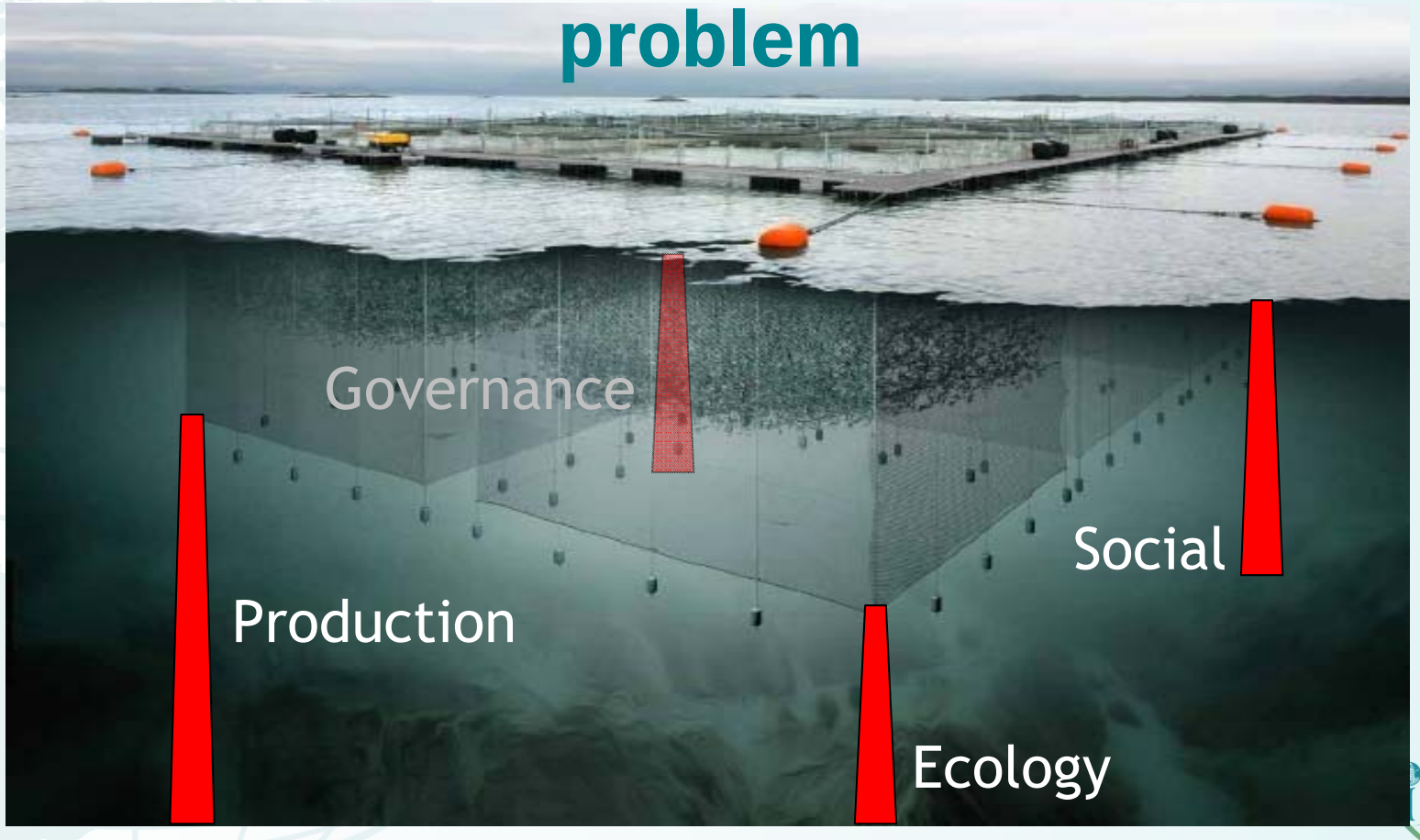
Where is shellfish aquaculture?





Carrying capacity – a multidimensional problem



Four pillars for sustainable aquaculture.

Background Information

- Sustainable Mariculture in northern Irish Lough ecosystems (SMILE) model: integrated framework for the determination of sustainable carrying capacity in shellfish production areas.

- Model combines field data, experimental results and various types of models, ranging from individual shellfish growth models to broad-scale ecosystem models.

- The model captures the essential information at each simulation scale, allowing decadal runs that provide results on cultivation of commercial species, nutrient and chlorophyll cycling.

- The modelling framework facilitates integrated analyses of animal-environment interrelations affecting overall production at system-scales, according to different temporal and spatial scenarios and accounting for conservation aspects such as the presence of wild species.

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Study Objectives

- Apply an ecosystem-based approach to the management of shellfish culture (TEASMILE) in Belfast Lough through the extension of the ecological model built for the SMILE project

- This was achieved by developing the wild species (natural benthic filter-feeder) component of the model

1. Interaction between natural benthic communities and cultivated shellfish (blue mussel, *Mytilus edulis)*

2. Effects of the above components on primary production and phytoplankton biomass, particularly with respect to top-down control of eutrophication




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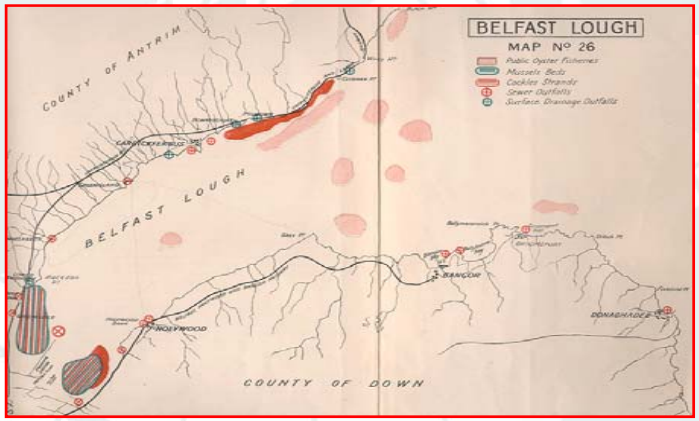
Legislative context

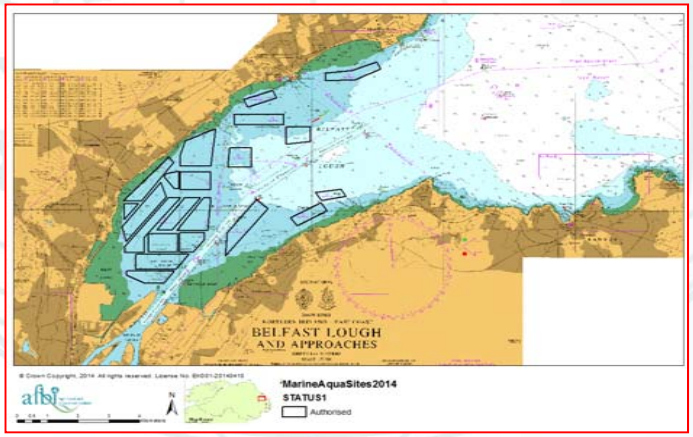
- Water Framework Directive (2000/60/EC) mandates that the biological quality element (BQE) phytoplankton abundance, biomass, and composition (ABC) must be at Good or High Status. Shellfish aquaculture can assist in organic extraction for top-down control of eutrophication

- Marine Strategy Framework Directive (2008/56/EC) includes descriptors for Biodiversity, Sea Floor Integrity, Fish and Shellfish, and Eutrophication. Relative balance of natural and cultivated benthic species is important

- The management decisions needed for both the WFD and MSFD are very complex. Results from models applied in TEASMILE support decision-makers for both directives

Case study: Belfast Lough





- Shallow semi-enclosed marine bay on the eastern coast of Northern Ireland
- 130 km^2 bay, catchment of 900 km^2
- Inner Lough: mudflats and lagoons. Outer Lough: mainly rocky shores with some small sandy bays
- 19th century: lough changed from a productive shellfishery to an industrialized port
- 70% of population of Northern Ireland lives in the catchment (nutrient input)
- Natura 2000 designated sites, Ramsar Site and ASSI
- Over 20 years of bottom culture mussel industry (*M. edulis*)

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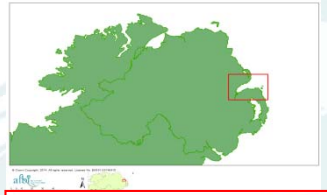
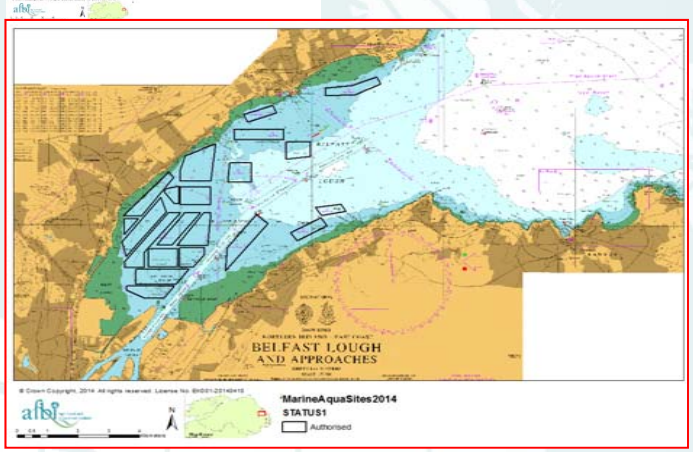
Case study: Aquaculture





- There are currently 21 licensed subtidal aquaculture sites for the culture of blue mussels (*Mytilus edulis*) within Belfast Lough
- The total area of Belfast Lough occupied by aquaculture is approximately 1,270 hectares
- Cultivation began in 1989. Belfast Lough is the largest production are for bottom grown mussels in NI. 50-75% of total NI mussel production.
- In Northern Ireland aquaculture is now worth over £6 million annually.

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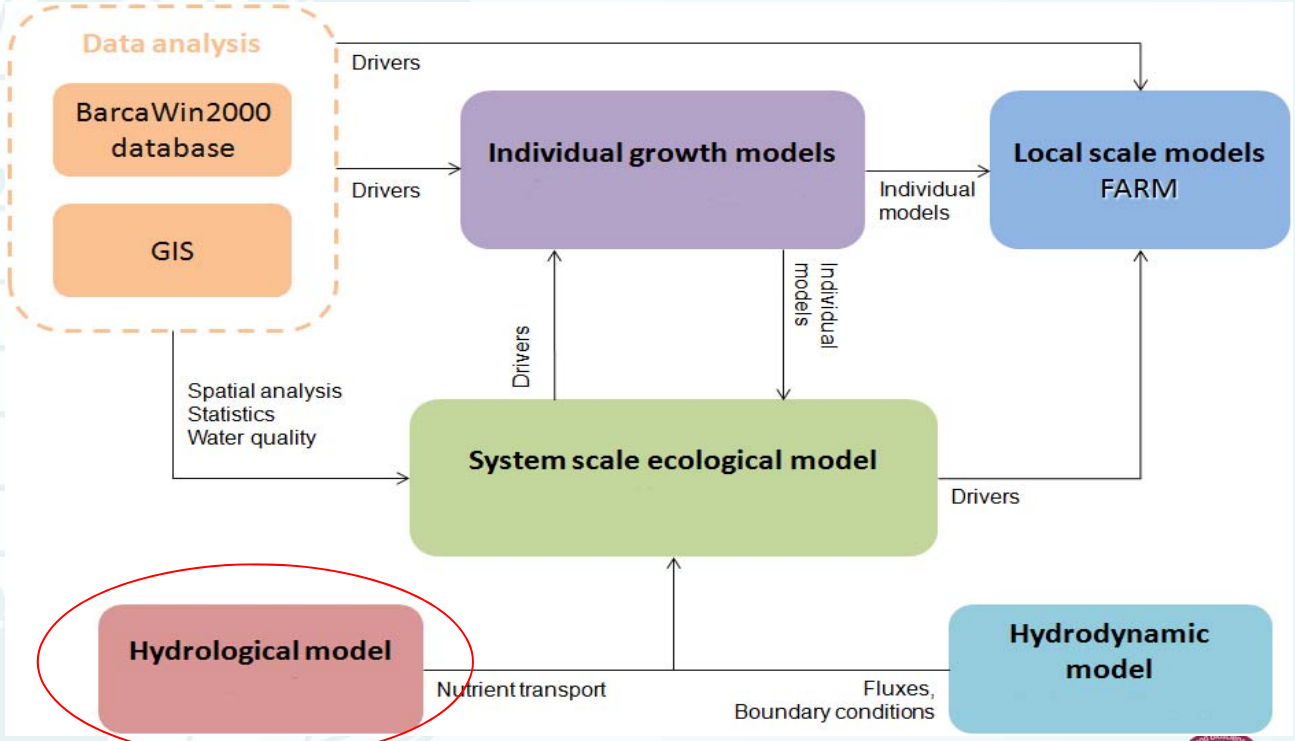
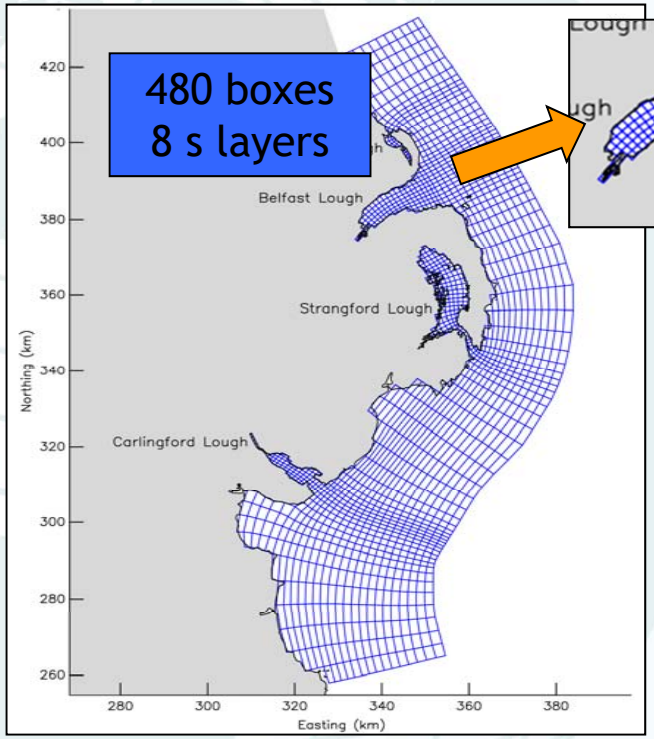
Model framework



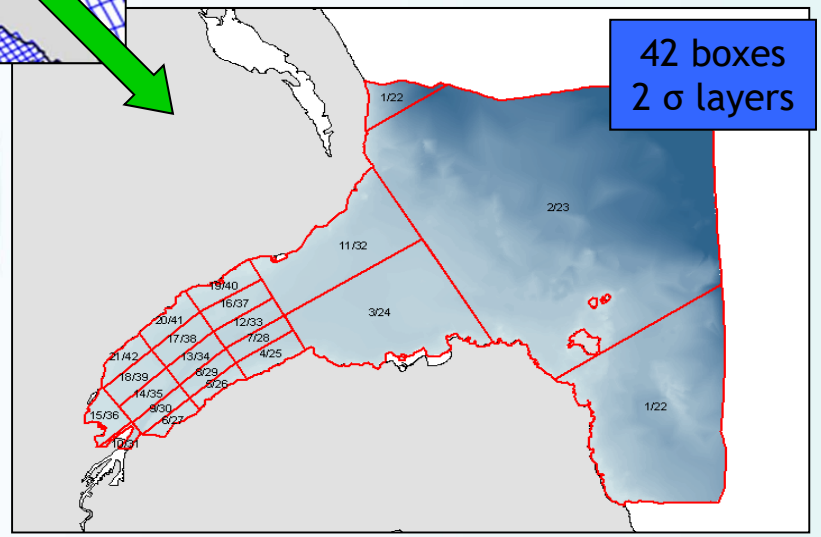
System-scale for budgets, farm-scale for direct recycling

Belfast Lough - hydrodynamics



Delft3D Hydrodynamic model

EcoWin2000
ecological model



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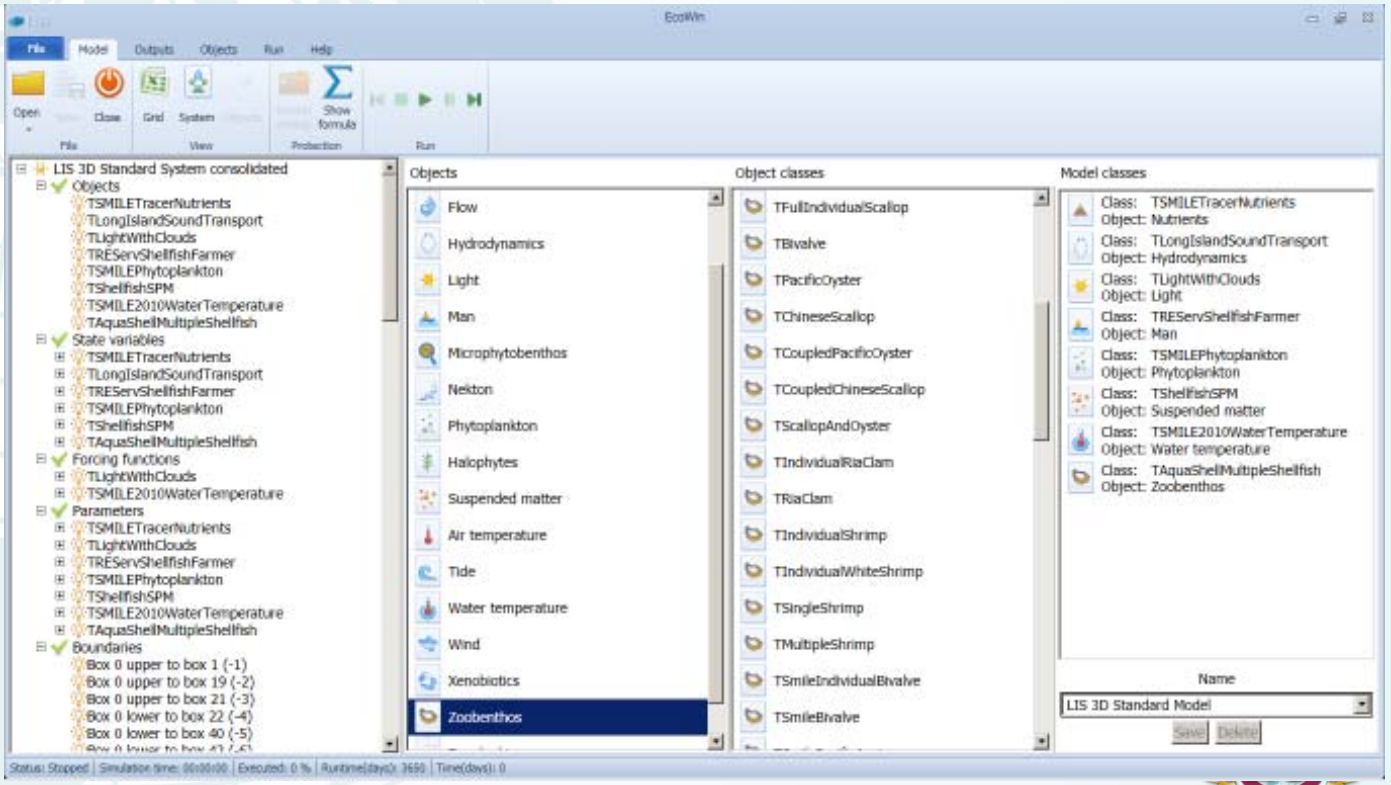
EcoWin.Net model – screenshot of objects library, 1992 - 2014



How did we use this? – study objectives

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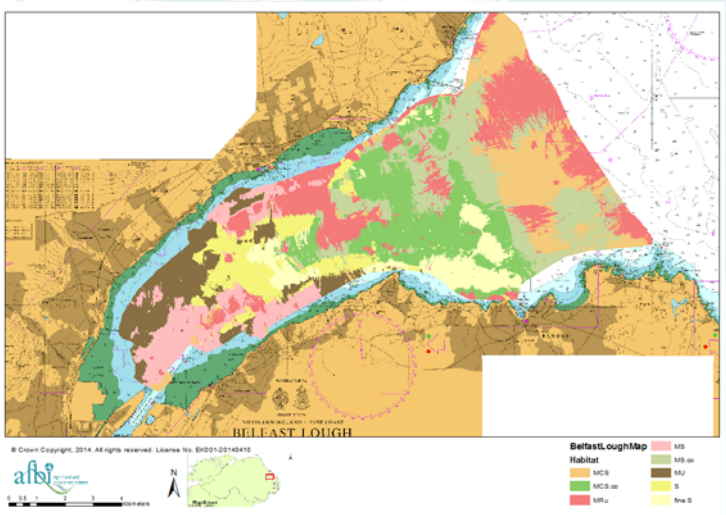
Why?

- SMILE evolved to adopt a more detailed ecosystem based approach by extending the ecological model as demonstrated here with TEASMILE – greater emphasis on ecosystem health

- Ensure model representative of natural ecosystem - populate model with real data for habitat and species – hence developing the wild species (natural benthic filter-feeder) component of the model

Interaction between natural benthic communities and cultivated shellfish

- EcoWin was expanded to include a detailed simulation of the benthic wild species:
  - 1. non-commercial benthic filter-feeders, species clustered as per associated habitat types
  - 2. commercially valuable natural (wild) species (intertidal mussels and cockles)



- Impacts of filter-feeders on primary production and phytoplankton biomass, with respect to top-down control of eutrophication.
- Support decision-making in context of WFD

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EcoWin.Net model – TEASMILE approach for wild species

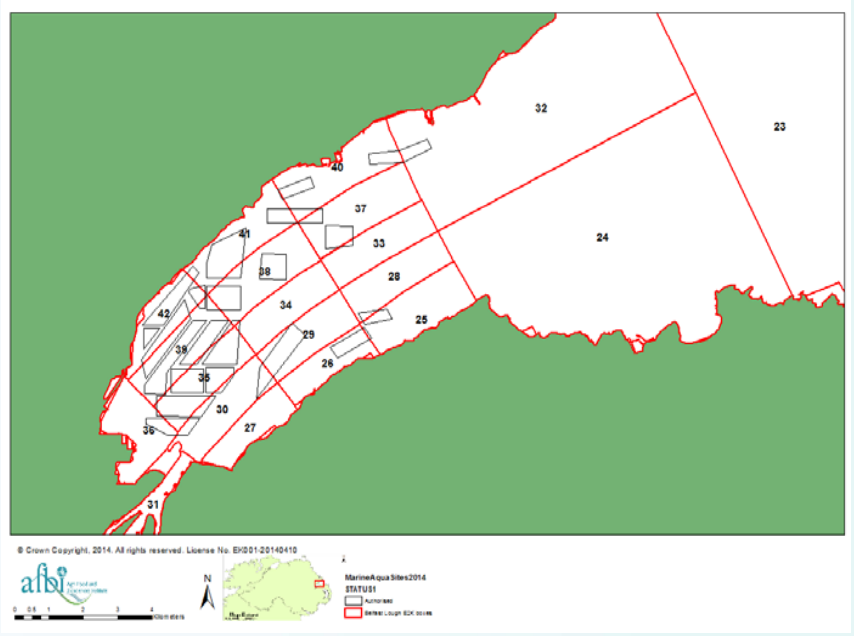
- Collate benthic grab data by species and abundance, analyse by means of clustering software;
- Select most representative species with respect to mean abundance. Around ten species will be chosen for each sediment category;
- Determine typical filtration rates for selected species, using literature data;
- Identify areas for the selected sediment types in each EcoWin box using GIS;
- Correct for unclassified areas per EcoWin box;
- Recode EcoWin to accept detailed data for wild species and simulate filtration and food removal;
- Add wild species data to EcoWin;
- Recalibrate and validate model;
- Explore development scenarios.

Effects on primary production and phytoplankton biomass

- **Run 1**: There was no aquaculture within the Lough (only natural wild species present). Used as Baseline.

- **Run 2**: **<u>All</u>** currently licensed aquaculture sites were activated at a rate of seeding (in terms of tonnage/ha) determined using the three year mean from observed data (2010-2012,DARD) plus baseline.

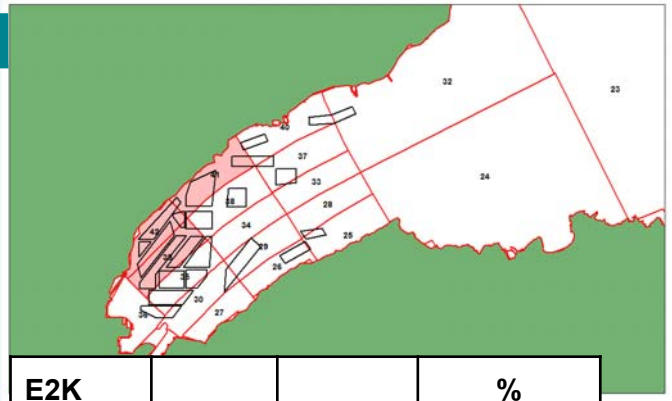
- **Chlorophyll a (Chl a) was used as a proxy for phytoplankton biomass.**



- Model boxes based on areas which have similar topography, biogeochemistry and using the Water framework Directive boxes as guidelines.

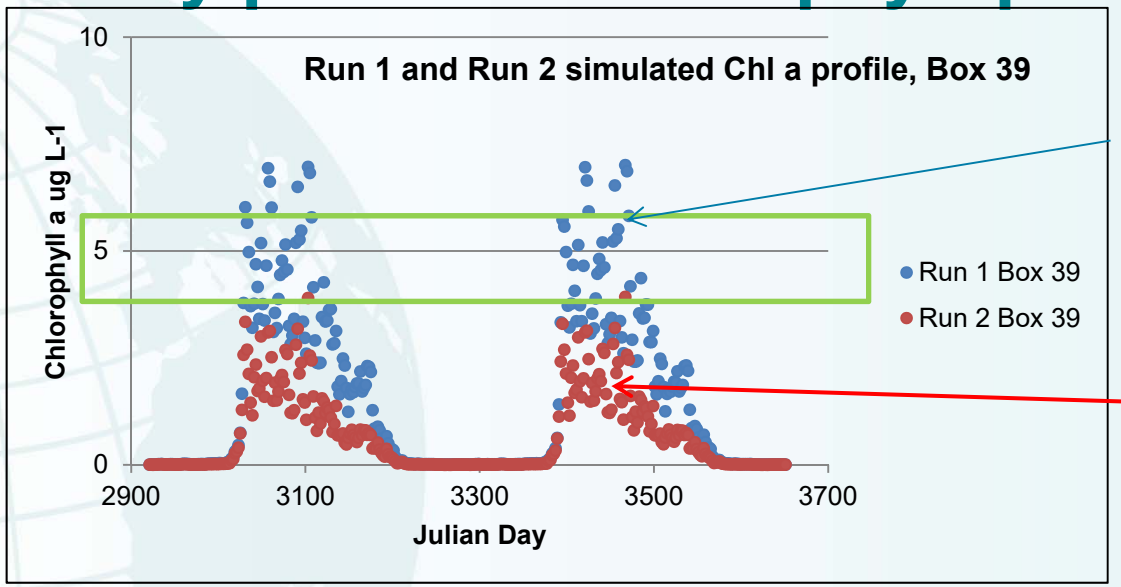
Effects on primary production and phytoplankton biomass

- Measured Chl a data in the lough shows an annual variation of up to a 41% recorded between sampling years.
- As a precaution a minimum of 50%, of baseline values of Chl a should remain for wild species.
- Hence aquaculture activities should not reduce Chl a concentrations by greater than 50% of baseline values.
- Table shows the % reduction in Chl a between the two model runs.



E2K Box	Run 1	Run 2	% reduction
Box 42	4.69	2.06	56.04
Box 39	3.83	1.75	54.40
Box 41	3.84	1.81	52.77
Box 36	4.83	2.60	46.27
Box 35	3.46	1.93	44.39
Box 40	2.87	1.65	42.44
Box 38	3.29	2.03	38.24
Box 30	5.42	3.89	28.25
Box 34	3.43	2.49	27.40
Box 29	4.08	2.98	26.97
Box 37	2.15	1.58	26.49
Box 31	5.19	4.07	21.55
Box 33	2.30	1.81	21.51
Box 26	5.33	4.23	20.79
Box 28	2.63	2.11	19.85
Box 25	2.75	2.32	15.72
Box 27	7.51	6.56	12.71
Box 32	1.26	1.14	9.49

Effects on primary production and phytoplankton biomass



Natural benthic communities (Baseline)

Active aquaculture

- Water Framework Directive (WFD), Coastal water body classification - percentile 90 Chl a in µg L^{-1} states; **< 5µg L^{-1} = high status** 5 – 10µg L^{-1} = good status.

Mussel feeding provides a valuable ecosystem service, reducing Chl a levels and **suppressing eutrophication** during summer months.

Conclusions

- Natural Benthic Communities exert top-down control
  - Variability due to habitat type and the abundance and diversity of wild species

- Aquaculture species exert top-down control in each of the lower model boxes
  - Variability is due to different intensity of aquaculture in each box

- An example is shown in Box 39 where aquaculture reduces the Chl-a concentrations to below the 5µg L^{-1} Chl-a WFD “high” threshold

- Shellfish aquaculture within Belfast Lough provides an ecosystem service while simultaneously contributing to local employment and food security.

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Thank you